Are ECG abnormalities common in black Africans with heart failure?
Results from the Heart of Soweto study

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ABSTRACT **Background: The "Heart of Soweto"
study is currently examining the pattern of cardiovascular
disease (CVD) in Soweto, South Africa.
Methods: As part of a large clinical registry of CVD patients
presenting to the Chris Hani Baragwanath Hospital in
Soweto, a 12-lead ECG was performed on 91% of
"de novo" cases in 2006. Systematic analysis of the ECGs of
heart failure patients was performed using detailed
Minnesota coding.
Results: A total of 756 de novo patients with HF (57%
women, 88% Black African and mean age of 55 ± 16 years)
had a 12-lead ECG. Overall, a major ECG abnormality was
detected in 91% of cases consisting of ST segment changes,
T wave changes, bundle branch blocks and arrhythmias.
Minor abnormalities were noted in 97% of ECGs, such as
axis deviation and high amplitude R waves. Left ventricular
hypertrophy was evident in 15% (22% in those with a dilated
cardiomyopathy) and a bundle branch block in 8% of ECGs
(11% in those with an ischemic cardiomyopathy).
Conclusion: Detailed examination of 12-lead ECGs of a
large group of previously undiagnosed patients with HF in
the Heart of Soweto study revealed many identifiable
abnormalities. In addition to reconfirming the clinical
utility of this cheap and practical diagnostic tool, these data
highlight its potential role in screening for heart disease,
particularly in low income communities.**

INTRODUCTION

Heart failure (HF) is a deadly and debilitating clinical syndrome that is the final and common pathway of numerous cardiovascular disease (CVD) states.[1] Preliminary data from the Heart of Soweto study (one of the largest studies of heart disease in Africa)[2] support the proposition that the phenomenon of epidemiologic transition and the subsequent emergence of more affluent forms of CVD seen in high income countries has broadened the pathways to the syndrome and increased the pool of affected individuals.[3]

In sub-Saharan Africa, HF has traditionally been caused by untreated rheumatic heart valvular disease, idiopathic and peripartum cardiomyopathy and hypertension.[4,5]

A particularly striking problem in this context is the usually late presentation of cases (i.e. where the antecedents to the syndrome have typically remained untreated, leading to clinically advanced forms of HF). The case in support of early detection and preventative treatment strategies is particularly strong in Soweto. However, those still imperfect strategies used to detect HF in high income countries, including systematic screening with brain natriuretic peptide assays[6] and rapid access echocardiography[7] may prove to be too costly and impractical in low to middle income countries such as South Africa.

A potentially cheap and useful diagnostic tool to detect HF in a relatively small number of adults living in large communities in low to middle income countries is the 12-lead electrocardiogram (ECG). Despite being "old" technology and commonly regarded as inferior to newer, more costly, technologies, the ECG still plays an important role in the clinical assessment of patients with CVD. The ECG provides information on the heart's position within the chest, electrical disturbances and electrolyte disturbances. Furthermore, it shows the mass of cardiac muscle and indicates the presence of ischemic changes reflecting possible coronary artery disease (CAD) or ventricular dysfunction. Many different tools have been developed to assess the 12-lead ECG, including Cornell voltage, Sokolow-Lynn voltage and Romhilt-Estes indices.[8-10] However, some authors have reported concerns with sensitivity and specificity.[9] In particular, the voltage indices show

differing results in determining LVH in an African-American population.[8]

In the presence of HF, there are particular abnormalities identified from the ECG that can characterize the syndrome, such as conduction abnormalities (e.g. bundle branch blocks, high amplitude R waves indicating hypertrophy and wide QRS complexes).[7] Indeed, one recent report from predominantly Caucasian populations living in high income countries indicated that over 90% of those with HF had an abnormal ECG.[7]

STUDY AIMS

The primary aim of this study was to undertake a preliminary analysis of ECG data derived from a large cohort of Black African patients with HF (confirmed by echocardiography) within the 2006 Heart of Soweto study cohort to determine the concurrent prevalence and type of major and minor ECG abnormalities. Ultimately, these data will be used to evaluate the role of 12-lead ECGs in detecting previously undiagnosed HF in this setting.

METHODS

Participants & Setting

As previously described in more detail, the Heart of Soweto study was established to investigate the prevalence and incidence of CVD within the townships of Soweto, South Africa.[2] As part of this study, we have systematically examined the volume, spectrum and pattern of clinical presentations in those attending the Cardiology Unit of the Chris Hani Baragwanath Hospital. The hospital provides health care to the estimated 1 to 1.5 million predominantly black Africans residing in the adjacent townships of Soweto. The study was approved by the hospital's Ethics of Human Research Committee.

As described in our index report from the Heart of Soweto study,[11] all first-time patients diagnosed with HF presenting to Chris Hani Baragwanath Hospital between the 1st January to 31st December 2006 were subject to a combination of echocardiographic assessment and review by a supervising cardiologist, in either the cardiac clinic or Coronary Care Unit. Only patients with confirmed HF (see diagnostic criteria below) were included in the study. This comprises a total of 844 patients with a combination of symptoms of HF and objective evidence of cardiac dysfunction (systolic and/or diastolic) at rest. As indicated above, all patients included in this report were subject to echocardiographic assessment with detailed assessment of ventricular function, valvular integrity and function and regional wall abnormalities

(specific measurements were available in all but 41 cases [5%]). Specifically, two-dimensional targeted M-mode echocardiography with Doppler colour flow mapping was performed using a Hewlett Packard Sonos 5 500 echocardiograph attached to a 2.5 or 3.5 MHz transducer. All echocardiographic procedures were undertaken by trained operators and measurements were made according to the American Society of Echocardiography guidelines.[12] Diastolic mitral flow was assessed by pulsed-wave Doppler echocardiography from the apical four-chamber view. The E wave deceleration time was also measured as the interval between the peak early diastolic velocity and the point at which the steepest deceleration slope is extrapolated to the zero line.

A detailed cardiac assessment was performed by a qualified or trainee Cardiologist to document lung and heart sounds and other clinically significant signs and symptoms. Functional status was also assessed to determine New York Heart Association Classification of dyspnea.[13]

Clinical classification

All cases were reviewed by SS and KS. These are based on European Society of Cardiology current guidelines[13] and the recently published European Heart Survey.[14] Based on the above process, the research team documented a clinical diagnosis for every individual included in the registry and captured close to 100% of their basic socio-economic and clinical profile from the standardized interview and assessments. The following forms of HF were identified as part of the clinical review process:

■ Left ventricular systolic dysfunction
  Left ventricular ejection fraction (LVEF) < 45%.

■ Diastolic dysfunction
  Classified based on E/A ratio and deceleration time according to generally accepted criteria.[12]

■ Dilated cardiomyopathy
  LVEF ≤ 45% and Left Ventricular Dimension in Diastole > 55 mm with global regional wall motion abnormality.

■ Ischemic cardiomyopathy
  LVEF < 45%, confirmed diagnosis of CAD and regional wall motion abnormality.

■ Hypertensive heart failure
  Blood pressure of > 180/100 mmHg accompanied by symptoms of HF (dyspnea and tachycardia), increased LV septal thickness (> 1.3 mm), diastolic dysfunction and/or systolic dysfunction (LVEF < 45%) by echocardiography.

■ **Valvular heart failure**

Secondary to primary underlying valve disease (e.g. rheumatic heart disease or degenerative valve disease) as opposed to underlying valvular dysfunction (e.g. mitral regurgitation) due to underlying cardiac dysfunction/failure.

■ **Right heart failure**

Secondary to right-sided pathophysiology with increased jugular venous pressure and liver size, tricuspid regurgitation and elevated right ventricular systolic pressure > 35 mmHg. Usually accompanied by peripheral oedema as unique or concomitant to left ventricular failure.

■ **Other forms of heart failure**

That includes congenital heart disease with delayed diagnosis made only in adulthood, hypertrophic obstructive cardiomyopathy, endomyocardial fibrosis, sub-mitral aneurysm, and secondary to infectious pericardial effusion.

On confirmation of the presence of HF, detailed clinical records were completed, including demographic data (age, race and sex with socio-demographic profile) and clinical data (encompassing blood pressure, anthropometric measurements, self-reported cardiac risk factors, functional status for angina and breathlessness). All patients were given a unique identifying code to allow further data analyses using the clinical registry. The total number of new "de novo" HF cases seen by the Cardiology Unit of the Chris Hani Baragwanath Hospital in the calendar year 2006 was 844. Of these, 756 (90%) had a documented 12-lead ECG that was entered into the clinical registry with a hard copy available for detailed analyses.

ECG analysis

A 12-lead resting ECG was performed by a trained technician and analysed by blinded reviewers (clinical cardiac nurses with advanced training) using the Minnesota Code Classification system.[15] Some had undertaken post-graduate diplomas in cardiac nursing and all worked in clinical nursing positions within cardiology. Two cardiac trained nurses (SS & GL) then independently verified these ECGs. The code allows systematic classification of Q and QS patterns, axis deviation, R waves, ST depression and elevation and T wave changes, along with conduction abnormalities in both atria and ventricles.[15,16] In addition to the Minnesota code, we also examined P wave changes (that is, left, right and biatrial changes that reflect atrial hypertrophy).

The abnormalities detected by the Minnesota code were pooled into major and minor abnormalities and separate analyses were performed

TABLE 1: Definition of ECG abnormalities and corresponding Minnesota codes[14]

ECG Abnormality	Minnesota Code
Major abnormalities	
Q and QS patterns (indicating myocardial infarction)	Code I_{1-2}
ST depression (Anterolateral, posterior, anterior)	Codes IV_{1-2}
Negative T waves	Codes V_{1-2}
Heart block (Wenckebach, Partial, Mobitz type II, complete heart block)	Codes VI_{1-2}
Ventricular conduction defects (Bundle branch block – complete or intermittent)	Codes VII_{1-2}
Arrthymias (Premature atrial or ventricular beats, atrial/ventricular fibrillation or flutter)	Codes $VIII_{1-3}$
Minor abnormalities	
Borderline Q wave abnormalities	Code I_3
Axis Deviation (left or right)	Codes II_{1-2}
High amplitude R waves	Code III_{1-2}
ST segment downward sloping	Code IV_3
Flattened T waves	Code V_3
Low QRS voltage	Code IX_1
Other abnormalities	
Ischemic findings	Codes I_3 or IV_{1-3} or V_{1-3} or VII_1
ST depression	Codes IV_{1-3}
Arrhythmias	Codes $VIII_{1-6}$ or $VII_{1-2, 4}$
Bundle branch blocks	Codes $VII_{1-2, 4}$
Left ventricular hypertrophy	Codes III_1 and (IV_{1-3} or V_{1-3})
Left axis deviation	Codes II_1

for ST segment depression, arrhythmias or AV blocks, bundle branch blocks and left axis deviation. The rationale for major and minor abnormalities was based primarily on a previous study by De Bacquer and colleagues[17] and the lack of consenses in other studies regarding the classification of ECG abnormalities.[9,10] [18-20] Also, there are potential clinical advantages in dividing ECG abnormalities into major and minor changes. The relevant Minnesota codes for each abnormality group are presented in Table 1.

Major abnormalities were defined as those with Q wave abnormalities, ST segment depression, T wave inversion, complete or second degree AV block, complete left or right bundle branch block (LBBB, RBBB), frequent premature beats, atrial fibrillation or flutter. Those with minor abnormalities were defined as borderline Q waves, left or right axis deviation, high amplitude R waves, borderline ST segment depression, T wave flattening and low QRS voltage. Sinus tachycardia was defined as a rate of >100 bpm and sinus bradycardia <50 bpm.

Data analysis

Simple frequency and correlational analyses of ECG abnormalities according to the underlying type of HF were performed using SPSS version 13.

RESULTS

Clinical & Demographic Profile

Of the 756 patients with a confirmed diagnosis of HF in the study cohort, 57% (n=478) were female, 88% (n=665) were black African and their mean age was 55 years (± 16 years). More than one recognizable HF antecedent was evident in over 90% of the sample, with 70% having hypertension, 47% being smokers and 34% being obese. The mean LVEF was 45 ± 18% with 27% presenting with diastolic dysfunction (the majority had preserved systolic function). Five predominant forms of HF were identified in this cohort: dilated cardiomyopathy (CMO) (n=251, 35%), hypertensive HF (n=242, 33%), right HF (n=193, 27%), valvular HF (n=49, 8%) and ischemic CMO (n=65, 9%). Black Africans were far more likely to present with a dilated CMO (OR 4.39, 95% CI 2.41 to 8.00) but far less likely to present with ischemic CMO (OR 0.11, 95% CI 0.07 to 0.19). Patients with dilated CMO (7% and 12%) and right HF (10% and 40%) were most likely to have moderate to severe mitral or tricuspid regurgitation.

Major and minor abnormalities

When applying Minnesota coding of each patient's 12-lead ECG, major ECG abnormalities (refer to Table 1) were recorded in 91% of HF patients. The most notable major abnormality was negative T waves in 57% of ECGs (n= 428) – refer to Figure 1. Other common abnormalities were ST segment depression in 21% (n=159) followed by Q waves in 18% (n=135). Only 3% of ECGs were normal.

Most ECGs indicated that patients were in sinus rhythm (n=475, 63%) or sinus tachycardia (n=198, 26%). A small number of patients (n = 13, 2%) had a heart rate < 50 bpm. A further 41 patients (5%) showed left anterior hemiblock and eight ECGs demonstrated intraventricular block. A close examination of P wave morphology revealed a left atrial abnormality in 100 patients (13%) and a further 93 ECGs (12%) demonstrated right atrial abnormality. Biatrial abnormality was evident in 60 ECGs (8%). In relation to the examination of AV conduction defects, three patients had an ECG suggesting a complete heart block, one patient a Mobitz heart block and two patients had pacemakers with appropriate capture. Three ECGs revealed a shortened PR interval, while 34 (4.4%) revealed a prolonged PR interval. A total of 64 patients (8%) were in atrial fibrillation or atrial flutter. Of these,

52 ECGs demonstrated persistent AF /persistent atrial flutter, with the remainder demonstrating intermittent AF.

A total of 97% of ECGs demonstrated minor ECG abnormalities (refer to Figure 2). Of these, the most common were axis deviation and high R wave amplitude (n=232, 31%), followed by flattened T waves in 24% of ECGs (n=179). Borderline ST segment depression (downward sloping ST segments) and borderline Q waves were observed in 48 ECGs (6%). Low QRS voltage was also recorded in 5% of ECGs (n=37).
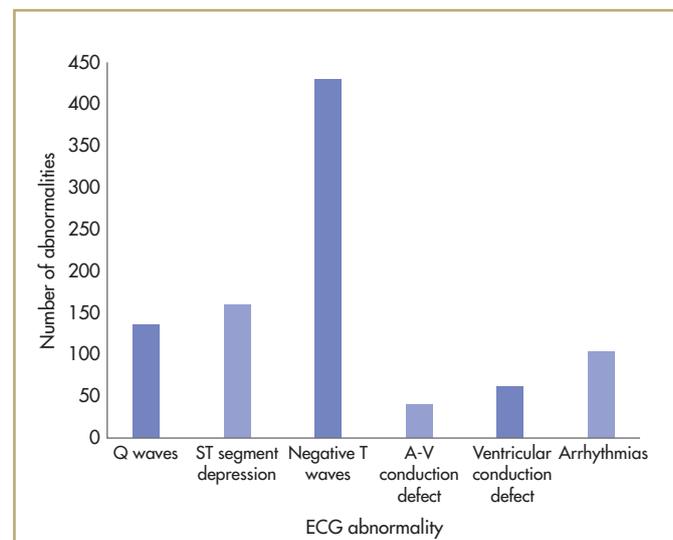

FIGURE 1: Frequency of major ECG abnormalities in 756 predominantly black African patients with HF
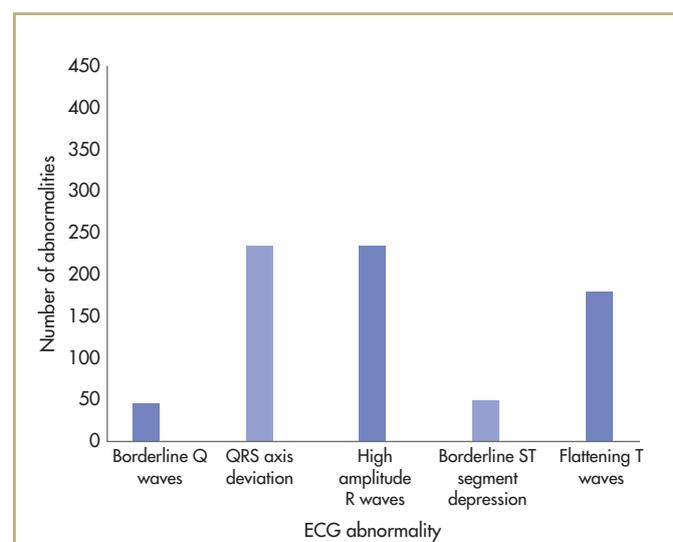

FIGURE 2: Frequency of minor ECG abnormalities in 756 predominantly black African patients with HF

ECG characteristics indicating possible HF

Specific characteristics that can be detected on a 12-lead ECG that are an indicator of HF include left ventricular hypertrophy (LVH), bundle branch blocks and axis deviation. Given that LVH is often associated with the development of HF (particularly in hypertensive individuals), it was interesting to note that ECG evidence of LVH was coded in 15% of this patient cohort (n=110). This was based on a Minnesota coding of isolated high amplitude R wave (code III_1) and either ST elevation (code IV_{1-3}) or T wave changes (code V_{1-3}).[15] Overall, LVH was observed in the ECGs of 54 patients with a dilated CMO (49%), 35 patients with hypertensive CMO (32%) and 22 of those with right HF (20%). In contrast, only four patients diagnosed with an ischemic CMO (3.6%) had ECG evidence of LVH (p < 0.001 for the comparison to all other diagnostic groups).

Figure 3 highlights the abnormalities typically observed on an ECG in a person with heart failure. It highlights tall R waves, ST segment changes and inverted T waves. All of these characteristics substantiate the probability of underlying LVH.

Bundle branch blocks are associated with HF and ventricular dysynchrony resulting in a decrease in cardiac output, adding to the already overburdened heart. With respect to ventricular conduction defects, (namely bundle branch blocks), a total of 32 ECGs (4%) had complete LBBB and 11 (1.5%) had RBBB. A further 13 (1.8%) had incomplete/intermittent RBBB and 14 (1.8%) had incomplete left bundle branch blocks.

Although the majority of ECG axes were normal (n=511), 130 (17%) indicated a right axis deviation and 107 (14%) a left axis deviation (see Table 2).

DISCUSSION

Examination of the ECG data on de novo HF presentations in the Heart of Soweto study revealed a high prevalence of ECG abnormalities. Specifically, we found that Minnesota coding of 12-lead ECGs revealed major and minor abnormalities in 91% and 97% of patients, respectively. As such, only 3% of ECGs were normal. Other ECG characteristics that are associated with HF (although these can also present with other pathologies) were shown in 8% of ECGs demonstrating bundle branch block, 15% with characteristics of LVH and a further 31% of ECGs had axis deviation. Thus the ECG plays a potentially important role in identifying abnormalities that are connected to a diagnosis of HF in
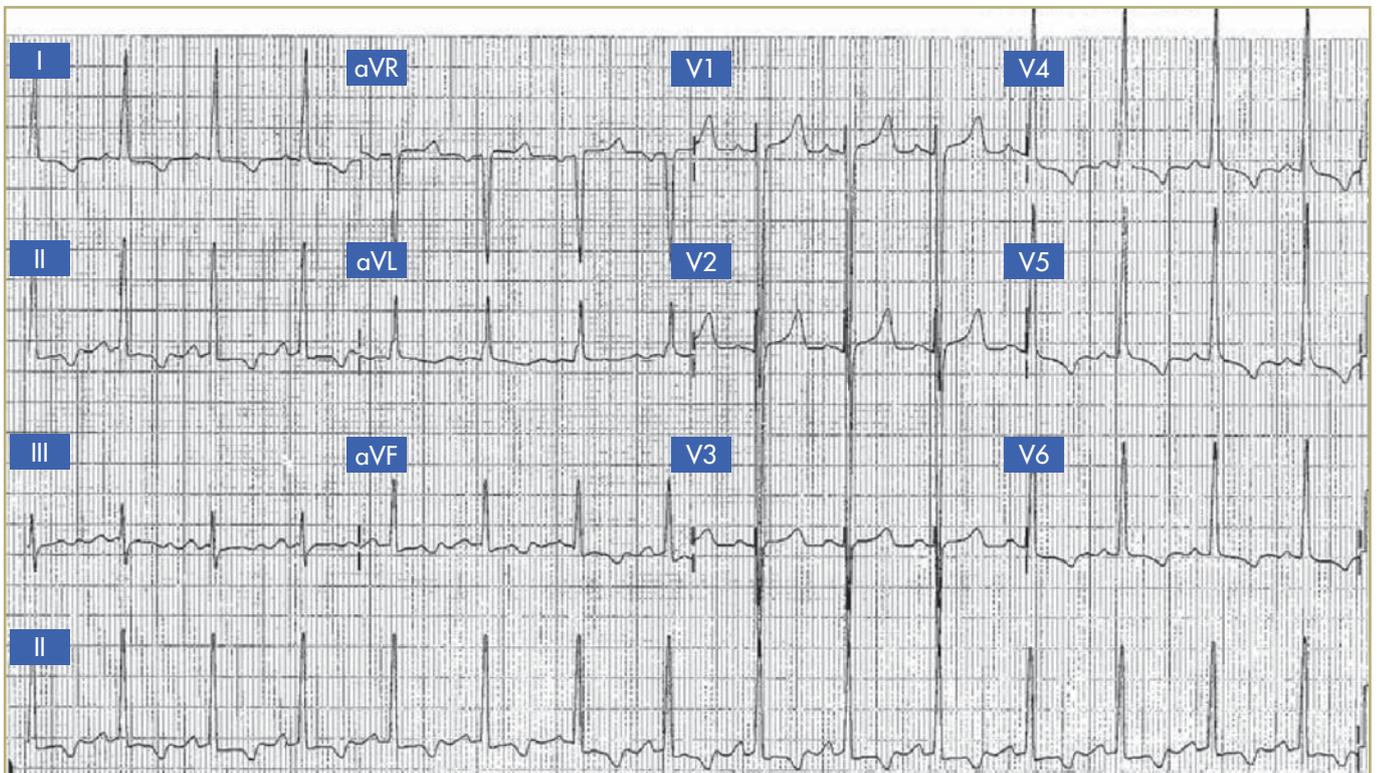

FIGURE 3: An example of a 12-lead electrocardiogram from a 45-year-old black South African female with hypertensive cardiomyopathy illustrating tall R waves, ST segment and T wave changes in the precordial leads (V1-V6).

TABLE 2: Axis and rhythm characteristics in this HF cohort

ECG Abnormality	Number of cases (%)
Axis	
Normal axis	511 (68%)
Left axis deviation	107 (14%)
Right axis deviation	130 (17%)
Extreme deviation	2 (0.2%)
Indeterminate	3 (0.3%)
Rhythm	
Sinus Rhythm	475 (63%)
Sinus Tachycardia	198 (26%)
Sinus Bradycardia	13 (1.7%)
Atrial fibrillation/flutter (persistent)	52 (6.8%)
Heart block	3 (0.3%)
Junctional arrhythmia	5 (0.6%)

this clinical setting of predominantly urban dwelling black Africans in South Africa.

In the present study, the majority of ECGs were abnormal. This was not surprising, however, since HF is the end result of poor cardiovascular health, which other conditions predispose the development of. The high number of abnormalities is in total agreement with previous studies that detected anomalies in the majority of ECGs of HF patients,[17,18] with one study reporting abnormal ECGs in 97% of patients.[17] The general consensus is that the ECG, in conjunction with patient symptoms, has an important role in guiding therapy and provides a basis for further investigation, that most likely being echocardiography.[18,19] It is also important to recognize that abnormal ECG findings strongly suggest the presence of abnormal cardiac functioning which, if left unmonitored and untreated, can lead to a diagnosis of HF.

Whilst a large number of HF patients had abnormal ECGs, more specific indications of HF from the ECG were detected in a smaller number of individuals. Overall, any ECG characteristic associated with HF (LVH, bundle branch blocks and axis deviation) were found in a total of 362 patients (48%). In comparison to the few studies in the literature that report the proportions of HF patients with ECG characteristics of HF, the number of LBBB observed on the ECGs in the current study was approximately one-third of that reported in other studies.[20,21] This discrepancy may be explained by the multiplicity of etiologies that can drive the development of HF (in this context from chronic hypertension to right heart failure to idiopathic CMOs). As such, in this cohort, in contrast to studies undertaken in high income countries where atherosclerotic disease predominates, ischemic CMO was the exception rather than the rule.[11]

There are many choices in determining an ECG classification tool. We chose to apply the Minnesota code to detect ECG abnormalities because it has been well validated, it is applicable to most populations compared to other indices[8] and, most importantly, it encapsulates the major ECG abnormalities that are important in describing an individual's electrophysiological function. A recent systematic review concluded that alternative electrocardiography indices deemed useful for detecting LV hypertension (Sokolow-Lyon index, Cornell voltage index, Cornell product, Gubner and Romhilt-Estes scores) suffered from poor accuracy.[9] Also, the amplitude of the signal voltage on ECGs poorly predicted LVH.[10] Finally, the Minnesota code has commonly been employed as a "prognostic" tool to determine long-term health outcomes and is associated with all-cause and CVD mortality.[8-10, 17, 22-24]

As an alternative marker of underlying ventricular dysfunction, brain natriuretic peptide (BNP) is a biochemical marker also used to detect HF and recommended to be used in conjunction with the ECG.[6] BNP is strongly related to the diagnosis of chronic heart failure (CHF), although the results have been less accurate in elderly patients and in women.[25, 26] A BNP of > 100pg/mL has been shown to provide relatively high sensitivity (89%) and specificity (73%) for diagnosing HF.[7,27] From a cost perspective, the unit cost of BNP is disproportionately more expensive compared to ECG but, due to differences in sensitivity and specificity in detecting HF, BNP becomes equally cost-effective as ECG.[7] These authors report that the gold standard strategy of traditional echocardiography alone was least cost-effective for screening, supporting that the ECG (or BNP) can be used cost-effectively for screening. Acknowledging the financial cost of treating and managing HF, the ECG clearly plays an important role. It may play an even greater role in low to middle income countries with a greater pool of individuals with more advanced forms of HF and where the cost constraints of using expensive bio-markers is more limited.

Pending further analyses to determine the sensitivity, specificity and positive predictive accuracy of the 12-lead ECG relative to gold standard echocardiography, these preliminary data indicate a potential role for the 12-lead ECG in any systematic screening program for HF in Soweto (and other communities). In the Heart of Soweto study, echocardiographic assessment was performed in all patients to determine ventricular function and functional abnormalities. However, the purpose of this paper was to highlight the ECG abnormalities independently of echocardiography. A correlation of the two measures will be performed in the near future.

This study has a number of limitations that require comment. For example, one of the disadvantages of a 12-lead ECG is that it is relatively brief in capturing a 10-second tracing of the heart's electrical activity, therefore risking missing transient changes. However, it is markedly advantageous over a 3-lead ECG, which provides very limited information. An important aspect is that the ECGs were not performed in isolation but in conjunction with other clinical measurements, thus allowing an in-depth assessment of an individual's clinical status. Although the 12-lead ECG is beneficial in aiding diagnoses and as a useful preliminary screening tool, the gold standard for a confirmatory HF diagnosis is the echocardiogram. One shortcoming of the Minnesota code is that it does not examine P wave abnormalities that indicate atrial enlargements and are associated with P mitrale (left atrial hypertrophy), P pulmonale (right atrial hypertrophy) or biphasic P waves (suggesting combined atrial hypertrophy). The detection of P wave abnormalities is considered important, as they may indicate untreated or poorly treated hypertension or represent some other unconfirmed pathology. To overcome this inconsistency in future applications of Minnesota coding of ECGs, we have decided to incorporate an examination of P wave abnormalities into our investigations.

Despite these limitations, and given the potential for the future rise of HF in Africa within the constraints of limited public health budgets, these preliminary data suggest that the 12-lead ECG has the ability to play a central role in identifying abnormal characteristics associated with conditions such as HF. As such, our detailed examination of a large group of previously undiagnosed patients with HF in the Heart of Soweto study revealed many identifiable abnormalities. In addition to reconfirming the clinical utility of this cheap and practical diagnostic tool, these data highlight its potential role in screening for heart disease, particularly in low income communities.

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